2.3.2 Brownlee Reservoir (RM 335 to 285)

The Brownlee Reservoir segment (RM 335 to 285) includes Brownlee Reservoir from Farewell Bend to Brownlee Dam (Figure 2.3.12). While Brownlee Reservoir contains three fairly distinct hydrological regions: the riverine zone near the tailwaters (roughly RM 335 to RM 325), the transition zone (roughly RM 325 to 305), and the lacustrine zone (RM 305 to 285); water management and water quality concerns are well correlated with the reservoir boundaries. The total reservoir volume is 1,420,000 acre-feet. The Upstream Snake River segment (RM 409 to 335) becomes the headwaters of the reservoir at RM 335. The Burnt and Powder Rivers flow directly into Brownlee Reservoir at RM 327.5 and RM 296 respectively, however, the inflow of these two tributaries is relatively minor (3.6% combined total) when compared with the inflow from the Upstream Snake River segment.

2.3.2.1 Introduction

Brownlee Reservoir has a total volume of 1,420,000 acre-feet, 975,000 acre-feet of which is available for storage (Table 2.3.12). Brownlee Reservoir at full pool has a surface area of about 14,000 acres, an elevation of 2,077 feet (mean sea level (msl)) and approximately 190 miles of shoreline. It is a long, deep system oriented predominantly in a north-south direction. The inflow to the reservoir is on the south end and the dam is located almost due north, approximately 52 miles downstream. The reservoir is relatively deep and narrow, occupying the canyon carved out by the Snake River. Reservoir depth ranges from approximately 30 feet at the upstream end to approximately 300 feet near the dam (IPCo, 1999d). Flow and residence time within the reservoir are controlled by outflows through Brownlee Dam. Average residence time is 34 days, however, with consideration of the additional internal processes of stratification, depth of withdrawal, flood control requirements and management for power generation, the residence time of water in different parts of the reservoir can vary considerably. Residence times generally decrease as flow increases. In an average year, nominal residence times (based on full-pool volumes) average 66 days. In a dry year (1992, 43.2% of a 30-year average), nominal residence time was nearly double that of an average year (130 days) (IPCo, 1999d).

Table 2.3.12 Physical characteristics of Brownlee Reservoir

Date Closed	1958
Full Pool (feet msl)	2,077
Minimum Pool (feet msl)	1,976
Total Volume (acre-feet)	1,420,000
Surface Area (acres)	14,133
Mean Depth (feet)	100
Length (river miles)	52
Mean Width (feet)	2,242
Shoreline (miles)	193
Average Retention Time (days)	34

Figure 2.3.12 Brownlee Reservoir segment (RM 335 to 285) of the Snake River – Hells Canyon TMDL reach.

The primary purpose of operation for Brownlee Reservoir is hydropower generation, which generally results in water level fluctuations of less than 10 feet (IPCo, 1999d). However, the reservoir is also operated for flood control under the jurisdiction of the US Army Corps of Engineers (USACOE), and participates in flow augmentation release scenarios designed to help anadromous fish move through the mainstem Snake and Columbia River systems. Reservoir releases in early spring are managed to assist migrating anadromous fish. Reservoir releases in the early fall are managed for downstream salmon spawning. Typical drawdown for flood control averages 40 feet. Maximum drawdown is approximately 100 feet (IPCo, 1999d).

Brownlee Reservoir contains three distinct zones: the riverine zone, the transition zone, and the lacustrine zone. Each zone represents different hydrological and pollutant transport/processing characteristics (Figure 2.3.13). The riverine zone is located in the upstream-most section of the reservoir (RM 340 to 325), and displays the most “river-like” flow characteristics. Water in this

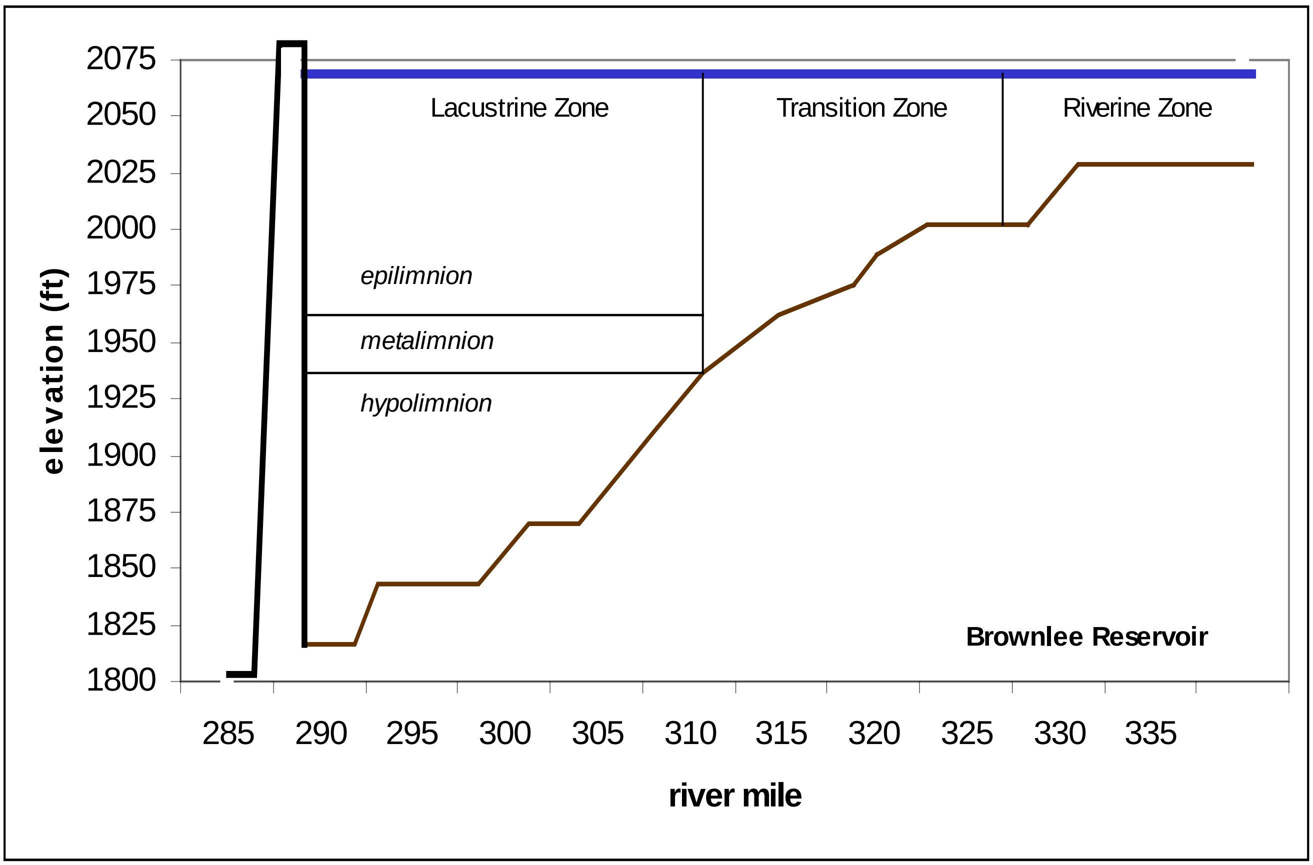


Figure 2.3.13 Location of separate reservoir “zones” within Brownlee Reservoir. (Brownlee Dam is located at river mile 285.)

zone is relatively shallow and exhibits higher velocities than downstream waters within the reservoir. Water quality in this zone is heavily influenced by the water quality of the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. During summer months, this zone routinely exhibits high concentrations of nutrients, organic matter and chlorophyll *a*. Wind action within this zone of the reservoir acts to mix inflowing waters, resulting in algae suspension throughout the water column. Productivity in this zone is observed to be high, which in turn increases the dissolved oxygen content of the water during photosynthesis.

The transition zone is located between the riverine and lacustrine zones of the reservoir (RM 325 to 308), and acts as a transition from the more river-like characteristics immediately upstream to the more lake-like characteristics immediately downstream. The transition zone is deeper than the riverine zone and flows are generally slower. As a result, sediment settles out at the upstream end of this zone. Inorganic sediment has accumulated between RM 325 and RM 315 due to this settling action. Algae settles out in this area also, drifting to depths where sunlight cannot penetrate. This settling results in death and decomposition, creating a high potential oxygen demand, and often depleting the dissolved oxygen content in the transition zone waters, especially in low flow years (IPCo, 1999d). In addition to the aquatic life habitat concerns associated with depleted dissolved oxygen levels, this combination of inorganic sediment and organic matter deposition, and anaerobic conditions can lead to the conversion of inorganic or elemental mercury to methylmercury which is much more easily absorbed by aquatic organisms than the elemental or inorganic forms associated with mercury from natural geologic deposits and legacy mining activities upstream.

The lacustrine zone is located between the transition zone and Brownlee Dam (RM 308 to RM 285). When the reservoir is thermally stratified (late spring to early fall), this zone is divided into three layers: the epilimnion, metalimnion and hypolimnion (Figure 2.3.13). Thermal stratification occurs to a greater extent in low and average water years than in high water years as the larger, late spring drawdowns common in high water years act to eliminate a portion of the deeper, colder water (IPCo, 1999d).

The epilimnion extends from surface elevation to approximately 35 m below the surface. This section of the reservoir generally exhibits higher dissolved oxygen concentrations than the metalimnion or hypolimnion during stratification. Dissolved oxygen levels are generally higher at the surface (up to 12 mg/L) and decrease with depth (to 0 mg/L near the metalimnion) (IPCo, 1999d). The epilimnion is the only layer within the lacustrine zone that experiences wind mixing.

The metalimnion extends from approximately 35 m below the surface to 45 m below the surface. The location of the metalimnion is directly associated with the placement of the dam outlet as releases from the penstocks act to pull water across the lacustrine zone. The location of the metalimnion is therefore less variable than would be expected if Brownlee Reservoir were a natural lake. Thermal gradients act to stabilize water within the hypolimnion, resulting in water from the transition zone moving laterally through the metalimnion with little vertical mixing. Dissolved oxygen concentrations are generally lower in the metalimnion than in the epilimnion due to this relative lack of mixing. Temperatures are also generally lower than those observed in the epilimnion.

The hypolimnion extends from 45 m below the surface to depth. During stratification, very low dissolved oxygen concentrations are consistently observed in the hypolimnion, due to oxygen demand from decaying organic matter and sediments. This low dissolved oxygen leads to the release of sediment-bound phosphorus and other constituents. However, the stratification of the reservoir, and the resulting lack of communication with surface waters, acts to isolate released nutrients from the surface waters during the growing season. With mixing, concentrations equilibrate within the reservoir and are discharged downstream with winter and spring flows.

For a more detailed discussion on the effect of impoundments on the SR-HC TMDL reach see Section 2.1.1.4. While most of the processes discussed in Section 2.1.1.4 can result in reduced water quality, impoundments can also act to improve water quality in downstream segments. As observed in the case of the Hells Canyon Complex, Brownlee Reservoir, located in the farthest upstream position, acts as a sink for both sediment and nutrients within the Hells Canyon Complex and downstream river segments. Brownlee Reservoir retains sediment and attached pollutants that might otherwise enter Oxbow and Hells Canyon reservoirs, and downstream reaches. In addition, downstream summer-season temperatures are reduced through deep-water releases from Brownlee Dam. Water is most commonly released at a depth of approximately 30 meters, which is well correlated with the location of the thermocline. It should be noted however, that while the above processes can result in improved water quality, the agencies prefer to prevent the initial pollutant loading into the system rather than to use instream retention systems (ODEQ, 1999).

2.3.2.2 WATER QUALITY CONCERNS/STATUS

General Information
The waters in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach are listed as water quality limited for dissolved oxygen, mercury, nutrients, pH, sediment and temperature.

Listed Pollutants and Designated Beneficial Uses
Table 2.3.13 summarizes the listed pollutants and designated beneficial uses for the Brownlee Reservoir segment (RM 335 to 285). A more detailed description of each of the designated beneficial uses is included in Section 2.2.2. A more detailed description of the listed pollutants and the assessment process is located in Section 3.0 through 3.7.

Salmonid spawning within this drainage basin is most likely to occur within the tributaries to the SR-HC TMDL reach where flow and substrate conditions are favorable to support such uses. Therefore, the salmonid spawning beneficial use designation and its accompanying water quality targets will apply to those tributaries so designated. As these tributaries are not interstate waters, and salmonid spawning use support is a localized habitat issue, state-specific targets for salmonid spawning will apply to those areas of the tributaries designated for salmonid spawning.

Cold water aquatic life, salmonid spawning (see above) and rearing, as well as resident fish are designated as beneficial uses in this segment.

The primary salmonid species in this segment are rainbow trout and mountain whitefish. The general spawning periods for these two species are March 01 to July 15 and November 01 to March 30, respectively. Resident fish species include such cool and warm water fish as bass, crappie, and catfish. In addition there is a small population of white sturgeon at the very upper end of this segment. The dominant fish communities in the Brownlee Reservoir segment (RM

335 to 285) are the resident cool and warm water fish. A more complete listing of fish species by segment is located in Section 4.6.

Summary and Analysis of Existing Water Quality Data

Dissolved Oxygen.
The Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach is listed as water quality limited due to low dissolved oxygen (DO) and potential for non-support of designated salmonid rearing/cold water aquatic life beneficial uses. Additional, more detailed information on dissolved oxygen is included in Section 3.2.

Table 2.3.13 Listing information for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	Idaho Listed Pollutants	Idaho Designated Beneficial Uses
Snake River: RM 347 to 285 Brownlee Reservoir (Scott Creek to Brownlee Dam)	Dissolved oxygen, mercury, nutrients, pH, sediment	Cold water aquatic life primary contact recreation domestic water supply special resource water
Segment	**Oregon Listed Pollutants**	**Oregon Designated Beneficial Uses**
Snake River: RM 335 to 260 Brownlee Reservoir Oxbow Reservoir Upper half of Hells Canyon Reservoir (Powder Basin)	Mercury, temperature	Public/private domestic water supply industrial water supply irrigation water, livestock watering salmonid rearing and spawning* resident fish and aquatic life water contact recreation wildlife and hunting fishing, boating, aesthetics hydropower

* Salmonid spawning within these drainage basins is most likely to occur within the tributaries to the SR-HC TMDL reach where flow and substrate conditions are favorable to support such uses. Therefore, the salmonid spawning beneficial use designation and its accompanying water quality targets will apply to those tributaries so designated. As these tributaries are not interstate waters, and salmonid spawning use support is a localized habitat issue, state-specific targets for salmonid spawning will apply to those areas of the tributaries designated for salmonid spawning.

<u>General Concerns</u>. See Section 2.2.4.1.
While there is potential for negative impacts to occur within the hypolimnion of Brownlee Reservoir because of the sediment release processes described in Section 2.2.4.1, the formation of a deep, strong thermocline limits the expression of these effects in Brownlee Reservoir. Instead, the effects of hypolimnetic processes in Brownlee Reservoir would likely be most prevalent in water being released downstream from the Brownlee Dam discharge.

<u>Water Quality Targets</u>. See Section 2.2.4.1 and Table 2.2.2.

<u>Common Sources</u>. See Section 2.2.4.1.
Elevated organic matter loading to Brownlee Reservoir results in low dissolved oxygen levels within the reservoir. Three primary mechanisms contribute to elevated organic matter loading:

organic matter delivered to the reservoir from upstream sources, organic matter produced as a result of elevated nutrient loading from upstream, and internal recycling of nutrients within the reservoir that result in algal growth within the reservoir. Blooms that form as a result of elevated nutrient levels can act to increase dissolved oxygen in surface water through photosynthesis. However, when algal death rates exceed algal growth rates, chemical processes in decomposition can act to consume dissolved oxygen faster than re-aeration from photosynthesis or mixing (IPCo, 1999d).

Historical Data. Data collected from 1968 to 1974 by the US EPA in the Brownlee Reservoir segment (RM 335 to 285) (near Brownlee Dam) show dissolved oxygen levels that average 7 mg/L in all available samples. No depth information is available with these data so location and water column variations are not known. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974a and 1975).

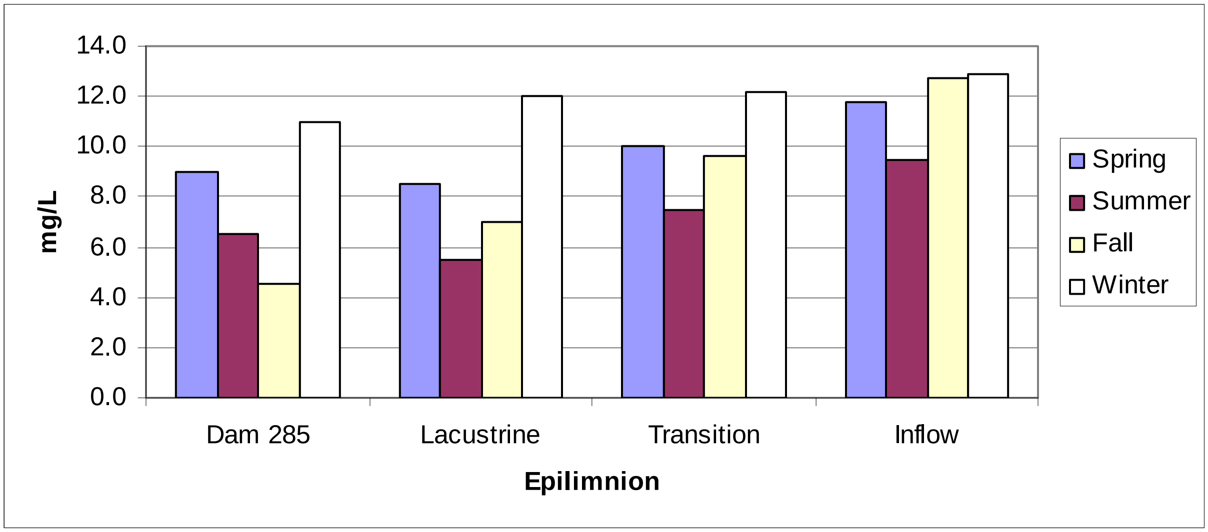
Current Data. As outlined in Table 2.3.14, dissolved oxygen concentrations have been monitored in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach for some time. Data currently available for this segment of the SR-HC TMDL reach includes dissolved oxygen monitoring at various locations and depths within the reservoir. While some dissolved oxygen data are available from US EPA (US EPA, 1998a), the majority of in-reservoir data has been collected by IPCo. A data set of dissolved oxygen concentrations measured at and below the thermocline, near the dam and in the lacustrine portion of the reservoir, shows that the water quality targets established by the SR-HC TMDL for cool and cold water aquatic life (6.5 mg/L) are not met nearly 100 percent of the time during July, August and September in dry and average water years. In wet years, targets are not met over 80 percent of the time during the months of July and August. Data collected during early summer and fall months (May and June, and October and November, respectively) show that the 6.5 mg/L dissolved oxygen targets are not met over 60 percent of the time in dry and average water years, and over 23 percent of the time in wet years. These same data show that targets are met routinely during the winter and spring months for all water years at and below the thermocline.

Table 2.3.14 Dissolved oxygen monitoring for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	Dissolved Oxygen Monitoring Dates	Source
Brownlee Reservoir (RM 335 to 285)	Monthly 1990 to present 1967 to 1996	IPCo, 1999d, 2000c US EPA STORET data, 1998a

Above the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data show that the water quality targets established by the SR-HC TMDL for cool and cold water aquatic life (6.5 mg/L) are not met approximately 50 percent of the time during the summer and fall months (July, August, September, October and November) in most water years. In the transition zone and the inflow to the reservoir, dissolved oxygen levels are generally in excess of the targets established by the SR-HC TMDL. These data show that targets are met above the thermocline in all sections of the reservoir routinely during the winter and spring months for all water years.

Dissolved oxygen concentrations vary seasonally and with variation in annual precipitation amounts. Low dissolved oxygen levels are most common in late summer, when water levels are low and air and water temperatures are high.



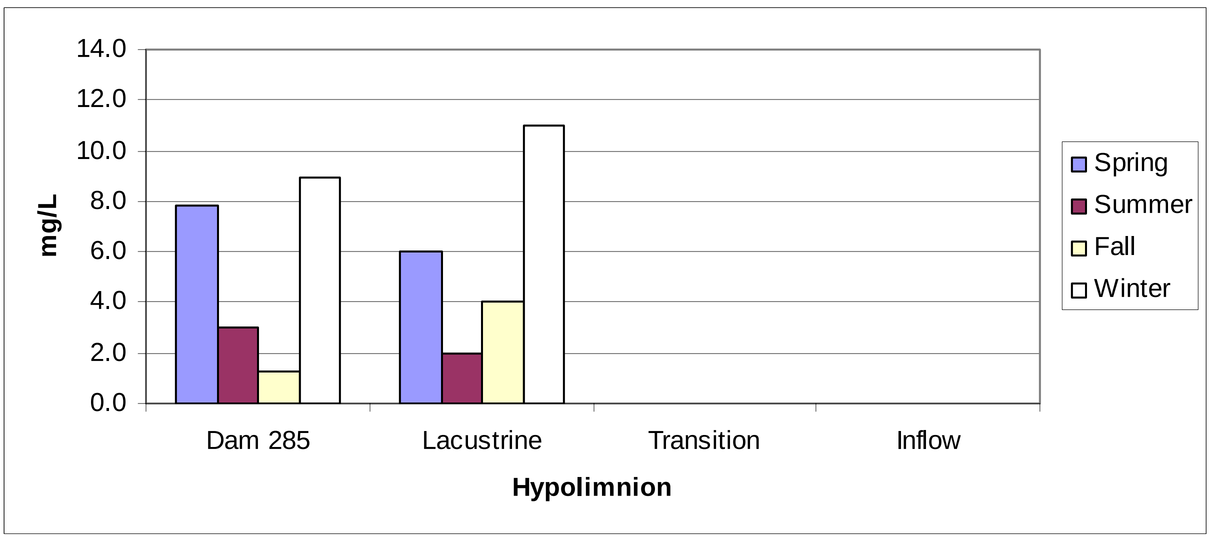


Figure 2.3.14 Mean dissolved oxygen concentrations for the Brownlee Reservoir segment of the Snake River - Hells Canyon TMDL (RM 335 to 285). Upper plot shows epilimnion dissolved oxygen concentrations, lower plot shows hypolimnion dissolved oxygen concentrations.

<u>Segment Status</u>. Within the reservoir, strong thermal stratification occurs during summer months (stratification usually occurs from March through November, but is strongest in July and August) (IPCo, 1999d). The position of the thermocline is well correlated with the level of the powerhouse penstocks, and extends approximately 25 miles upstream of the dam. Below the thermocline, notable anoxia (dissolved oxygen concentrations of less than 6.5 mg/L) has been observed to occur, especially during summer months (Figure 2.3.15). Dissolved oxygen concentrations from 0.5 to 2.0 mg/L are common during this time period in the lower levels of

the reservoir where cooler temperatures occur. This phenomenon is thought to be primarily the result of high levels of organic material in the water column as opposed to high sediment oxygen demand (IPCo, 1999d). Hypoxia occurs most extensively within the lacustrine sections of the reservoir during low and average flow years, although some volume of the deeper water level has experienced low levels of dissolved oxygen in high flow years also. A similar situation occurs in the transition zone of the reservoir. This hypoxic zone forms at the bottom of the water column, but can extend nearly to the surface and includes a substantial volume of the transition zone during low and average flow years (IPCo, 1999d).

The upper layers of the transition zone of Brownlee Reservoir show a very strong increase in dissolved oxygen (10 to 16 mg/L) during the late summer (August and September) which correlates well with the observed algal productivity in the river at this time (IDEQ, 1993a; IPCo, 1999d). Low dissolved oxygen, combined with high summer water temperatures can have significant negative affects on fish and other aquatic life. In July of 1990, low dissolved oxygen throughout the water column resulted in an extensive fish kill in the transition zone of Brownlee Reservoir. The fish kill included all species including at least 28 white sturgeon (IPCo, 1999d).

Although the Snake River historically may have experienced some level of algal production and probably some depletion of dissolved oxygen, the system was changed substantially with the completion of the Hells Canyon Complex. Decreases in dissolved oxygen concentrations stemming from nutrient and organic loading to the system have been exacerbated by the physical modifications that have been made to the system. Thus dissolved oxygen concerns in the reservoir result from <u>both</u> external loading and physical modification to the river system. Reductions in incoming nutrients and organic matter (including algae) from upstream sources, together with correlated efforts to improve dissolved concentration on the part of IPCo will act to improve water quality within the reservoir system.

Available data and information indicate that the cold water aquatic life and salmonid rearing designated beneficial uses are impaired during the summer months in Brownlee Reservoir. Concerns related to increased mercury methylation due to anoxia and presence of excessive organic matter are also present, especially in the upstream segment of the reservoir.

Available data from the tributaries to Brownlee Reservoir show that most meet the 6.5 mg/L minimum water column target for cool and cold water aquatic life year round IPCo, 2000a, USGS, 1999; US EPA, 1998a). These tributaries provide cold water refugia during the summer months for some species in the reservoir.

Mercury.

The Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach is listed as water quality limited due to human fish consumption advisories issued by the states of Oregon and Idaho for mercury (Appendix D). Additional, more detailed information on mercury is included in Section 3.1.

<u>General Concerns</u>. In addition to the general information available in Section 2.2.4.2, methylation of mercury is of specific concern within the reservoir environment. Low dissolved oxygen levels and the presence of a substantial amount of organic material near the

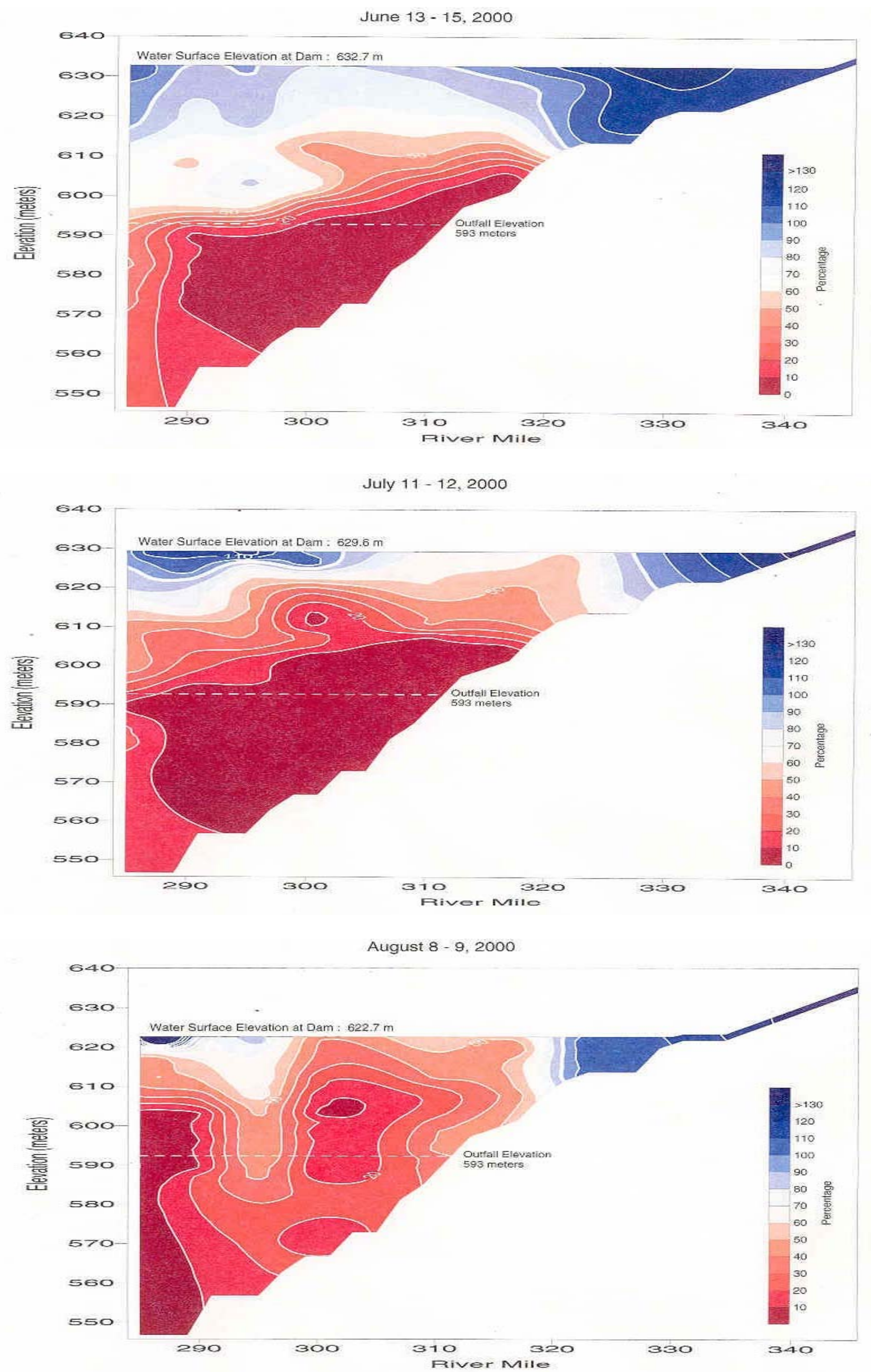


Figure 2.3.15 Dissolved oxygen isopleths for Brownlee Reservoir (data collected and plots prepared by Boise City Public Works).

sediment/water interface can result in higher rates of methylmercury production, as available hydrocarbon materials from the organic matter are available to bond with elemental mercury. Methylmercury represents a significantly greater threat for bioconcentration and accumulation than elemental or mineralized mercury compounds as it is much more soluble in water and therefore much more mobile within both the physical reservoir system and the metabolic systems of living organisms living in or using the water.

Water Quality Targets. See Section 2.2.4.2 and Table 2.2.2.

Common Sources. See Section 2.2.4.2.
Sediment samples collected and analyzed for mercury content in both the Upstream Snake River segment (RM 409 to 335) and the Brownlee Reservoir segment (RM 335 to 285) showed that the highest concentrations of sediment-associated mercury were observed at RM 335 and RM 340. However, sediment related mercury has been observed within the Brownlee Reservoir segment as well (IPCo, 2000d).

Historical Data. The earliest mercury measurements in this segment date to the early 1970s, post construction of the Hells Canyon Complex as shown in Table 2.3.15. However with changes in sampling and analytical techniques it is difficult if not impossible to correlate monitoring prior to 1970 with current data.

Current Data. As outlined in Table 2.3.15, mercury levels have been monitored in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach over an extended period of time. The most recent data collection and analysis occurred in 1997 (Clark and Maret, 1998) and 1999 (IPCo, 2000d). However, the data available for Brownlee Reservoir are fish tissue and sediment concentrations, with no associated water column concentration data.

Table 2.3.15 Mercury monitoring for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	Mercury Monitoring Dates	Source
Brownlee Reservoir (RM 335 to 285)	Jan 1970 April 1994 Aug 1997 Summer 1999	Buhler *et al.*, 1971 (OSU) IDEQ data Clark and Maret, 1998 (USGS) IPCo, 2000d

Segment Status. Because of the lack of water column data, it is not possible to compare data directly to the SR-HC TMDL water column mercury target. However an indication of the mercury status of this segment can be found in the fish tissue and sediment data. It is apparent that from the 1970s until present, this segment has exhibited mercury levels in fish tissue that are of concern for human health (US EPA, 2001a, 2001b, 2001c).

The data collected in 1994 and 1997 indicate that exceedences of the State of Oregon action level may be occurring in individual fish tissue samples. Data collected in 1990 and 1997 (Table

2.3.16) show a decrease in average methylmercury concentration, however, this data set is insufficient to demonstrate a conclusive downward trend for two reasons: 1. Data from 1970 cannot be compared directly due to differences in analytical techniques. 2. Size, age, weight and species differ from data set to data set and are therefore not directly comparable. Further monitoring, during the first phase of implementation may help to determine if the lower fish tissue methylmercury concentrations observed in the recent data collected from the Brownlee Reservoir (RM 335 to 285) segment of the SR-HC TMDL reach are representative of actual conditions.

Table 2.3.16 Mercury in fish tissues in the Brownlee Reservoir segment (RM 335 to 285) over the past 30 years. Note: All averages represent data over several species and age classes.

Year	Number of Samples	Mean* Mercury (mg/kg wet weight)
1970	33	0.51 (range = 0.24 to 0.97)
1994	130	0.39 (range = 0.24 to 0.60)
1997	5	0.26 (range = 0.11 to 0.33)

* These values are means. The range is based on the mean measured methylmercury concentration observed for a species, not an individual fish. Therefore, in 1994 some individual fish tissue data exceed the action levels set by both the State of Oregon and the State of Idaho. In 1997, some individual fish tissue data may exceed the action level established by the State of Oregon.

Methylmercury produced in this section of the river has the potential to effect not only local aquatic life, but that downstream as well, as the methylmercury produced will be carried downstream by the water flowing further into Brownlee Reservoir and on into downstream segments. Increased availability of methylmercury in this and the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach can be directly related to the production and deposition of organic material (algae, periphyton, etc.).

The action level for fish tissue mercury concentrations for the State of Oregon is 0.35 mg/kg. The action level for fish tissue mercury concentrations for the State of Idaho is 0.5 mg/kg (wet weight). All fish tissue data available in the SR-HC TMDL reach were positive for mercury. The Oregon and Idaho levels of concern for methylmercury in fish tissue were exceeded by 80 percent and 52 percent respectively. Based on these data, both states have fish consumption advisories in place.

Data show impairment of the designated beneficial use of fishing. Available data and information demonstrate a high level of concern for the wildlife and hunting designated beneficial use due to observed fish tissue methylmercury concentrations. Collection of water column data is required to determine the status of cold water aquatic life, salmonid rearing, resident fish and aquatic life, domestic water supply designated beneficial uses, and any trends that may be occurring.

Nutrients.

The Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach is listed as water quality limited due to nuisance algal growth from excessive nutrient loading. This condition generates concern due to the negative effect excessive algal growth can have on dissolved oxygen and pH. Additional, more detailed information on nutrients is included in Section 3.2.

General Concerns. See Section 2.2.4.3

Water Quality Targets. See Section 2.2.4.3 and Table 2.2.2.

Common Sources. In addition to the common sources described in Section 2.2.4.3, additional sources of nutrients to the Brownlee Reservoir segment (RM 335 to 285) may include natural levels of phosphorus carried in by the Snake River from the mountains that rim the southeastern border of the Snake River Basin as discussed previously. Anthropogenic releases of phosphorus to the Snake River from roadways and vehicle-related disturbances, livestock grazing, mining and smelting of phosphate ores upstream (US EPA, 1974a) are also carried into the reservoir by the inflowing Snake River.

Historical Data. Anecdotal information for upstream segments indicates that algal growth may have occurred at noticeable levels before extensive anthropogenic impact to this reach from agricultural practices or urbanization occurred (US EPA, 1974a). While there is no available mechanism to extrapolate this information to algal or nutrient concentrations in the river, one logical interpretation of this would be that noticeable algal growth accumulated in the river system. Data collected from 1968 to 1974 by the US EPA in the Brownlee Reservoir segment (near Brownlee Dam) show total phosphorus levels that average of 0.08 mg/L. Similarly, nitrate/nitrite levels in this segment averaged 0.5 mg/L. No depth information is available with these data so location and water column variations are not known. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974a and 1975).

Current Data. As indicated in Section 2.2.4.3, the two major nutrients of concern in algal productivity are phosphorus and nitrogen. In systems dominated by cyanobacteria (blue-green algae), such as the Brownlee Reservoir segment (RM 335 to 285) at some times of the year, phosphorus is usually the limiting agent.

Available data for Brownlee Reservoir includes water samples from within the reservoir and tributaries discharging into the Brownlee Reservoir segment of the SR-HC TMDL reach (Tables 2.3.17 and 2.3.18). The data represents both grab samples and depth-integrated information. While some nutrient and chlorophyll *a* data are available from US EPA (US EPA, 1998a), the majority of in-reservoir data has been collected by IPCo.

Total Phosphorus. At and below the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data show that the water quality target established by the SR-HC TMDL for total phosphorus is routinely not met during July, August, September and October.

Table 2.3.17 Nutrient monitoring for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	Nutrient Monitoring Dates	Source
Brownlee Reservoir (RM 335 to 285)	Monthly 1990 to present 1967 to 1996	IDEQ, 1993a IPCo 1999d, 2000c US EPA STORET data, 1998a

Table 2.3.18 Algae monitoring for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	Algae Monitoring Dates	Source
Brownlee Reservoir (RM 335 to 285)	Monthly 1990 to present 1978 to 1996	IDEQ, 1993a IPCo 1999d, 2000c US EPA STORET data, 1998a

Data collected during winter and spring months show the lowest levels of total phosphorus (0.04 mg/L to 0.08 mg/L). Data collected during September and October show the highest total phosphorus concentrations (0.4 mg/L to 0.6 mg/L). These data show that while nutrient targets are not routinely met at or below the thermocline during the winter and spring months, values are routinely lower overall during this time period.

Above the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data show that the water quality target established by the SR-HC TMDL for total phosphorus is routinely not met during July, August, September and October. Data collected during early summer months show the lowest levels of total phosphorus (0.02 mg/L to 0.03 mg/L). Data collected during September and October show the highest total phosphorus concentrations (0.1 mg/L to 0.2 mg/L). These data show that while nutrient targets are not routinely met above the thermocline during the winter and spring months, values are routinely lower overall during this time period.

In the transition and inflow portions of the reservoir, combined data show that the water quality target established by the SR-HC TMDL for total phosphorus is routinely not April, May, June, July, August and September. Data collected during the winter months show the lowest total phosphorus concentrations (0.03 mg/L to 0.06 mg/L). Data collected during the spring months show the highest levels of total phosphorus (0.4 mg/L to 0.6 mg/L). These data show that while nutrient targets are not routinely met during the fall and winter months, values are routinely lower overall during this time period.

Ortho-Phosphate. At and below the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data collected during the spring and early summer months show the lowest levels of ortho-phosphate (0.03 mg/L to 0.06 mg/L). Data collected during September, October and November show the highest ortho-phosphate concentrations at or below the thermocline (0.3 mg/L to 0.4 mg/L).

Above the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data collected during early summer months show the lowest levels of ortho-phosphate (0.01 mg/L to 0.02 mg/L). Data collected during September and October show the highest ortho-phosphate concentrations at or above the thermocline (0.10 mg/L to 0.12 mg/L).

In the transition and inflow portions of the reservoir, combined data collected during the spring and summer months show the lowest ortho-phosphate concentrations (0.01 mg/L to 0.02 mg/L). Data collected during the fall months show the highest levels of ortho-phosphate (0.3 mg/L to 0.4 mg/L.

Chlorophyll a. At and below the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data collected during the late summer months show the lowest levels of chlorophyll *a* (~0 ug/L to 1 ug/L). Data collected during November and December show the highest chlorophyll *a* concentrations (5 ug/L to 10 ug/L). These data show that the threshold value of 15 ug/L chlorophyll *a* is not routinely exceeded in this area of the reservoir.

Above the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data collected during the winter months show the lowest levels of chlorophyll *a* (2 ug/L to 6 ug/L). Data collected during the early spring and summer show the highest chlorophyll *a* concentrations (50 ug/L to 80 ug/L). These data show that the threshold value of 15 ug/L chlorophyll *a* is routinely exceeded during the early spring and summer months in this area of the reservoir.

In the transition and inflow portions of the reservoir, combined data collected during the mid-summer and winter months show the lowest chlorophyll *a* concentrations (1 ug/L to 25 ug/L). Data collected during the spring and late summer months show the highest levels of chlorophyll *a* (200 ug/L to 275 ug/L). These data show that the threshold value of 15 ug/L chlorophyll *a* is routinely exceeded during the spring and late summer months in this area of the reservoir.

Mean values of total and ortho-phosphate (Figure 2.3.16) in Brownlee Reservoir show a decreasing trend with increasing distance downstream. During the critical summer months (May through September) when conditions for algal growth are optimal, concentrations at RM 335 (in the riverine section near Farewell Bend) average 0.14 mg/L total phosphorus, 0.03 mg/L ortho-phosphate and 30 ug/L chlorophyll *a* (1995 to 1999). At RM 325 (near the upstream end of the transition zone) concentrations average 0.12 mg/L total phosphorus, 0.02 mg/L ortho-phosphate and 48 ug/L chlorophyll *a* (1995 to 1999). At RM 315 (in the middle of the transition zone) concentrations average 0.09 mg/L total phosphorus, 0.04 mg/L ortho-phosphate and 23 ug/L chlorophyll *a* (1995 to 1999). At RM 305 (near the downstream end of the transition zone) concentrations average 0.08 mg/L total phosphorus, 0.04 mg/L ortho-phosphate and 18 ug/L chlorophyll *a* (1995 to 1999). At RM 285 (in the lacustrine zone near the dam) concentrations average 0.06 mg/L total phosphorus, 0.04 mg/L ortho-phosphate and 6 ug/L chlorophyll *a* (1995 to 1996).

Data collected for determination of phosphorus concentrations (both reservoir and inflow data) vary seasonally and with variation in annual precipitation amounts. Inflow data varies seasonally with changes in agricultural recharge, dilution from spring runoff, and subsurface contributions. Annual variations also result from relative precipitation amounts, frequencies and intensities.

Reservoir data varies with depth, season, level of stratification, dissolved oxygen concentration and location within the system. Substantial depositional differences may also result from storm events and drawdown or release scenarios; depending on precipitation amounts, frequencies and intensities.

Because of the interaction of nutrients, algae, dissolved oxygen and pH, algal biomass has been monitored through sampling and analysis for chlorophyll *a* and pheophytin (a metabolite of chlorophyll *a*). Data available from both nutrient and algal monitoring has been identified as an

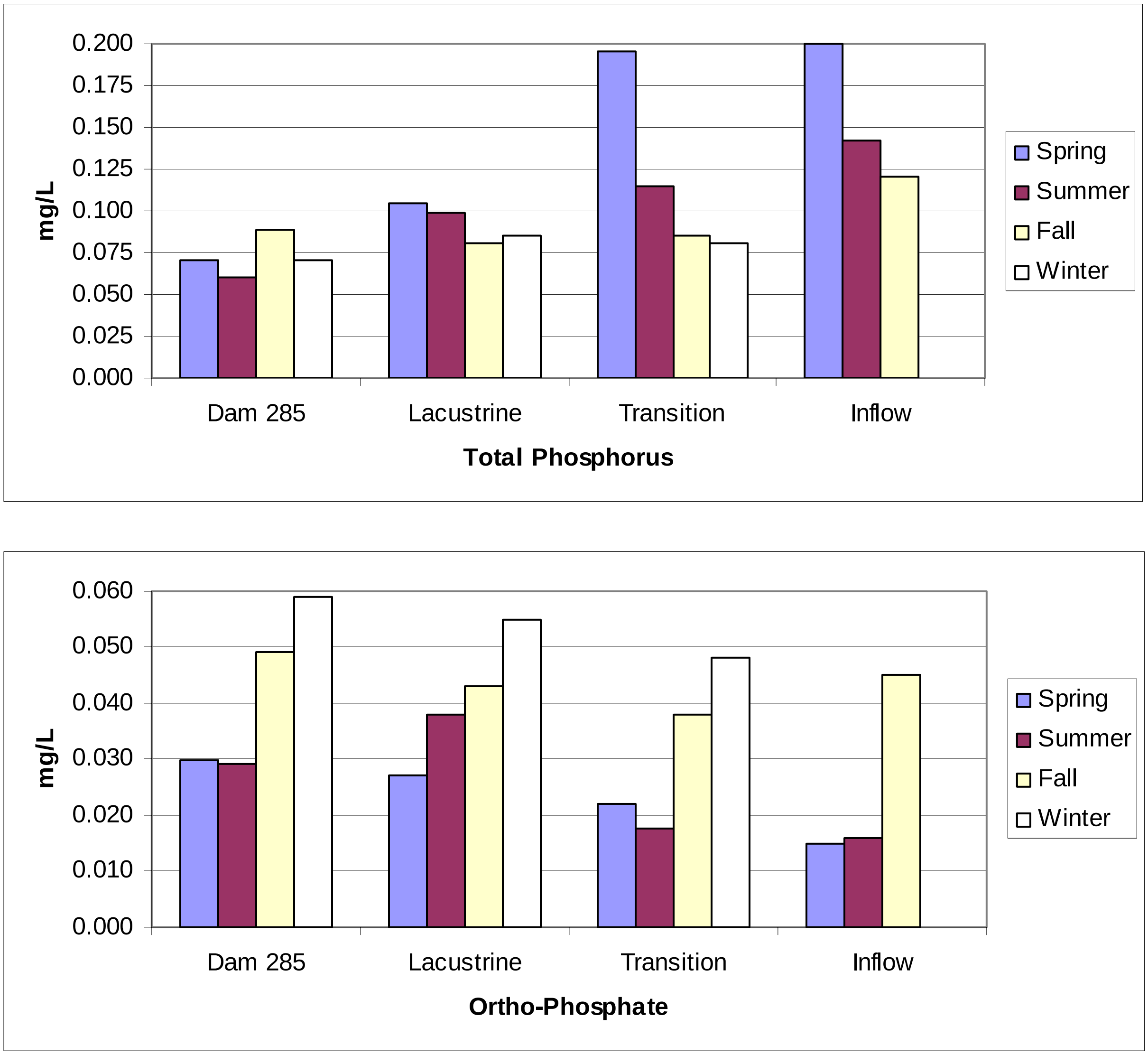


Figure 2.3.16 Mean total phosphorus (upper plot) and ortho-phosphate (lower plot) concentrations for the Brownlee Reservoir segment of the Snake River - Hells Canyon TMDL (RM 335 to 285).

important part of the assessment of water quality. Therefore, these data have been included in the monitoring information on algae even though they are not specifically listed as parameters on the 303(d) list.

Segment Status. Recent monitoring shows that within the Brownlee Reservoir segment (RM 335 to 285), incoming water quality influences in-reservoir water quality (IPCo, 1999d; IDEQ, 1993a). In the case of phosphorus loading, a less than or equal to 0.07 mg/L total phosphorus concentration is the SR-HC TMDL target. Total phosphorus monitoring data collected from inflows to Brownlee Reservoir consistently exceed these values. Available data show that in years with low and average annual precipitation levels (1992 to 1996), the median total phosphorus concentration in inflowing water was consistently 0.12 to 0.24 mg/L. Median

Brownlee Reservoir concentrations (Figure 2.3.17) at the same time were approximately 0.1 mg/L (IDEQ, 1993a; USGS, 1999; US EPA, 1998a). Ortho-phosphate made up approximately 30 percent of the total load in the mainstem Snake River, and averaged 57 percent of the total load from the inflowing tributaries. In an average water year (1995 to 1996) the median total phosphorus concentration in inflowing tributary waters ranged from 0.2 to over 0.3 mg/L. Median mainstem Snake River concentrations at the same time ranged from approximately 0.1 to 0.2 mg/L (IPCo, 1998a, 1999d, 2000a, 2000c, 2000d; US EPA, 1998a; USGS, 1999). Ortho-phosphate made up approximately 50 percent of the total load in the mainstem Snake River and the inflowing tributaries. Dissolved reactive phosphorus isopleths, are shown in Figure 2.3.18.

In general, total phosphorus concentrations observed at the mouth of the Burnt and the Snake Rivers are the highest of the inflows while those in the Powder River are the lowest in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. In general, ortho-phosphate concentrations observed at the mouth of the Burnt River are the highest of the inflows while those in the Powder and Snake Rivers are lower.

Within the reservoir, stratification occurs during summer months, resulting in dramatically different phosphorus concentrations above and below the thermocline. Total phosphorus concentrations below the thermocline tend to be higher than those above the thermocline, averaging 0.25 and 0.1 mg/L respectively (IPCo, 1999d). Ortho-phosphate concentrations also differ above and below the thermocline. When anoxic conditions occur within the reservoir, ortho-phosphate is released from bottom sediments and enters the water column. Because of strong stratification, much of this desorbed ortho-phosphate is trapped below the thermocline and is not available for algal production in the reservoir during the critical growing season. This is evidenced by ortho-phosphate concentrations in the waters at or below the thermocline that average from 3 to 5 times higher than those observed in the surface waters.

Seasonal nitrate and total kjeldahl nitrogen concentrations are shown in Figure 2.3.19 for the separate reservoir zones. Nitrate concentrations below the thermocline tend to be higher than those above the thermocline. Nitrate concentrations in the surface layers average 0.61 mg/L, which is considerably lower than those below the thermocline, which average 1.3 mg/L (IPCo, 1999d; US EPA, 1998a).

In addition to the nutrient loads entering the system, algae is both grown in place in the reservoir and delivered to this segment from the inflowing tributaries. Growing season reservoir conditions provide adequate light penetration as occurrences of high turbidity are generally associated with spring runoff, and temperatures within the upper water column will support growth. Available data show that chlorophyll *a* concentrations are generally highest in the riverine zone of the reservoir (RM 333 to 340) (Figure 2.3.20). Blooms also tend to occur most commonly in the transition zone of the reservoir (RM 302 to 328) during the late spring (March and April) and late summer months (August and September) (IPCo, 1999d).

A study completed during a very dry water year (IDEQ, 1993a) showed that chlorophyll *a* ranged from 70 to 100 ug/L above and at the transition zone respectively. Data collected near the dam during this same time frame (IPCo, 1999d) show chlorophyll *a* concentrations were

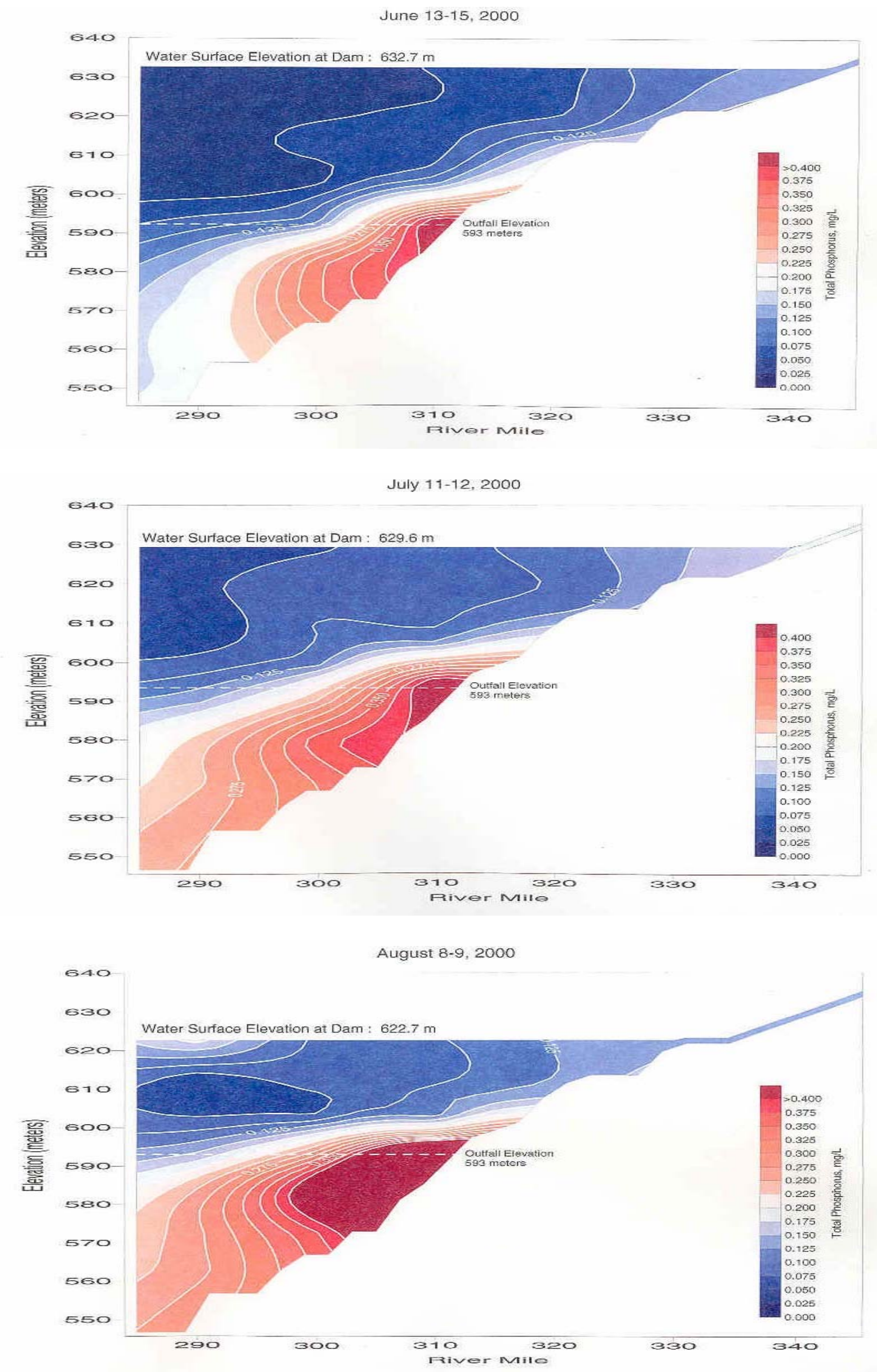


Figure 2.3.17 Total phosphorus isopleths for Brownlee Reservoir (RM 335 to 285). Data collected and plots prepared by Boise City Public Works.

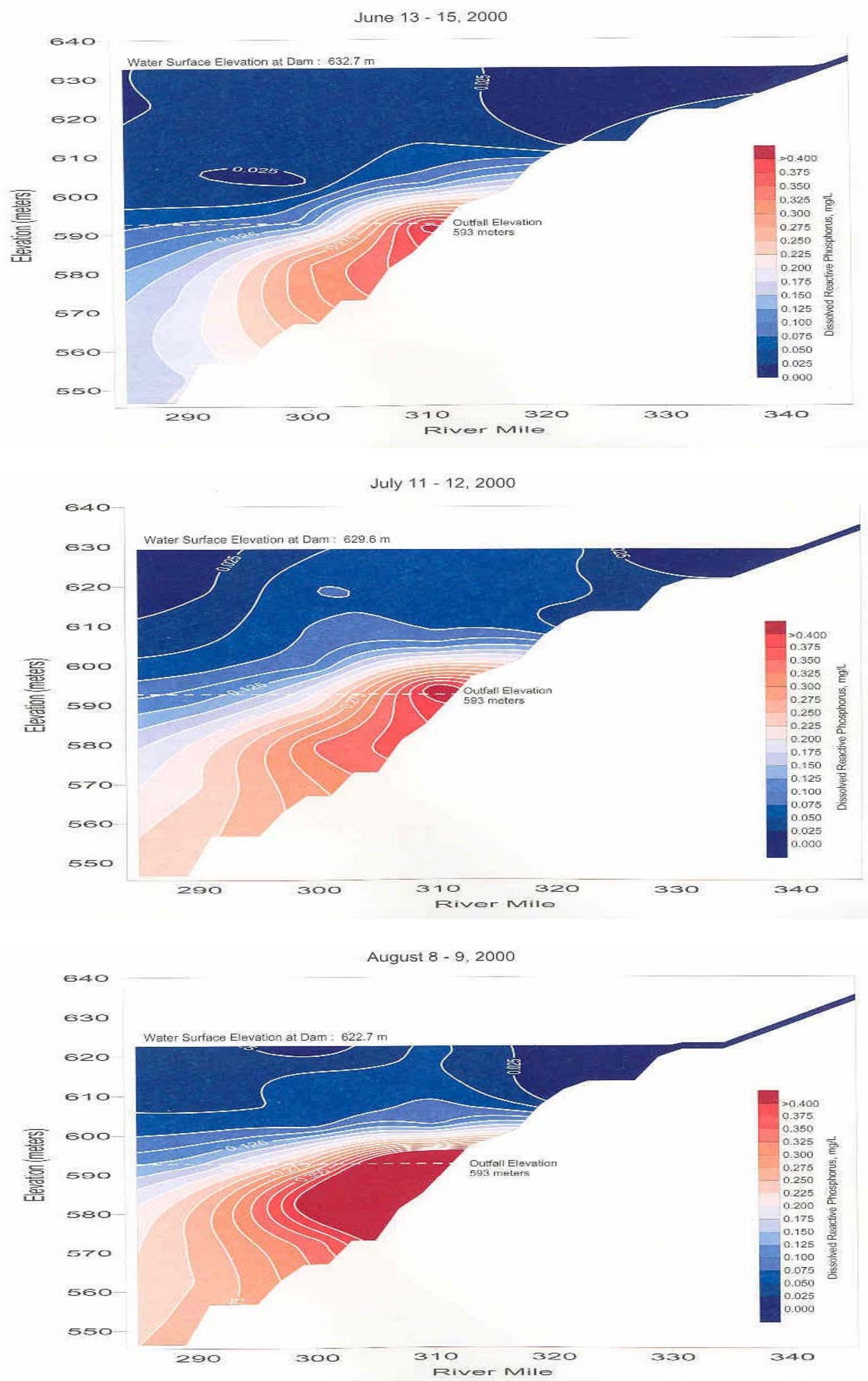


Figure 2.3.18 Dissolved reactive phosphorus isopleths for Brownlee Reservoir (RM 335 to 285). Data collected and plots prepared by Boise City Public Works.

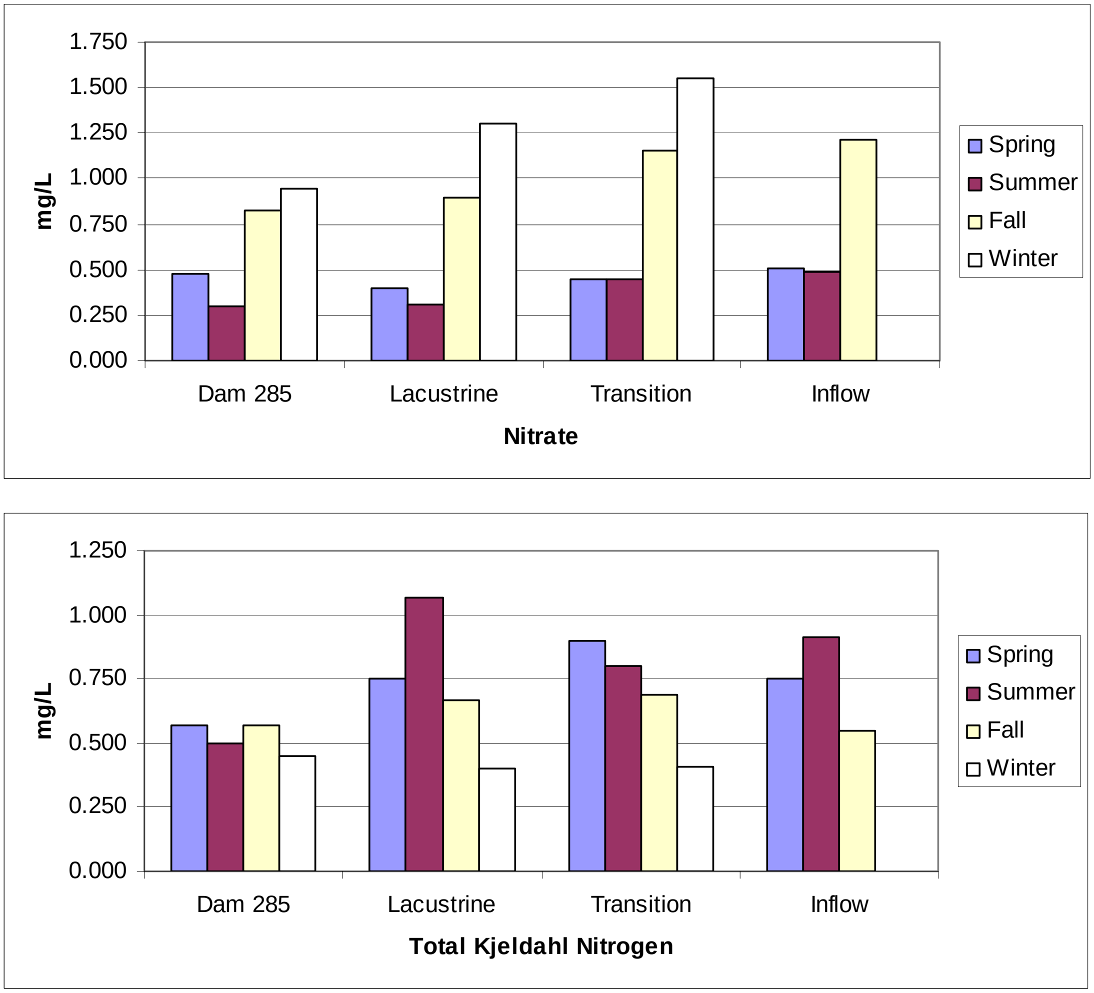


Figure 2.3.19 Mean nitrogen concentrations for the Brownlee Reservoir segment of the Snake River – Hells Canyon TMDL reach (RM 335 to 285).

markedly lower (5 to 10 ug/L). More recent monitoring (1995 through 1997) supports this trend with chlorophyll *a* levels in the riverine and transition zone routinely observed to be five times higher than those observed near the dam.

The algal populations within the reservoir change from upstream to downstream reservoir segments. The riverine zone in Brownlee Reservoir, with faster moving water and less stratification provides more favorable conditions for diatom species than for blue-greens, which is similar to the Upstream Snake River segment (RM 409 to 335). When the water enters the lacustrine section of the reservoir however, cyanobacteria (blue-green algae) become more prevalent due to high inflowing nutrient levels and slower water velocities.

Cyanobacteria (blue-green algae) have small sacs or vacuoles inside their cell membranes. By adding air to these sacs (rather than respiring to the outside) the algae can increase their buoyancy and move upward in the water column. Similarly, by removing air from these

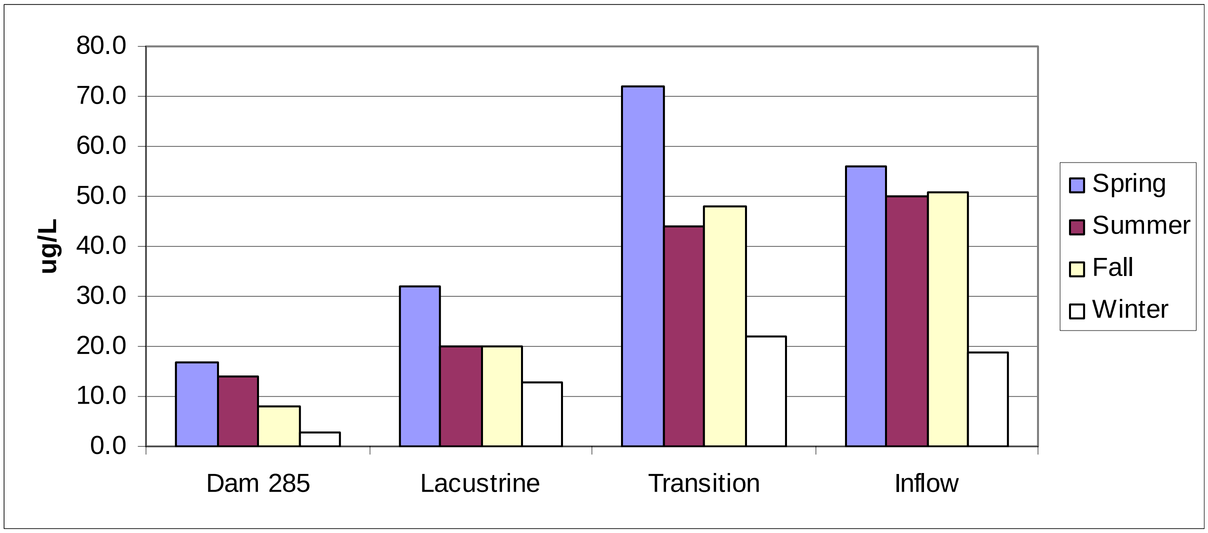


Figure 2.3.20 Mean chlorophyll *a* concentrations for the Brownlee Reservoir segment of the Snake River – Hells Canyon TMDL reach (RM 335 to 285).

vacuoles, the algae can move downward in the water column when nutrients in the immediate surface layers are depleted. This allows the algae to have a greater chance at surviving during major bloom events that remove dissolved nutrients from the upper layers of the water column. This ability of cyanobacteria (blue-green algae) to regulate their position in the water column becomes a greater advantage in this section of the reservoir and allows the blue green species to dominate (IPCo, 1999d). Dense blooms often occur in the transition zone, located between these two distinct sections, contributing to hypoxia in this zone of the reservoir.

While surface blooms of cyanobacteria (blue-green algae) may occur in the reservoir, total algal biomass tends to be higher in the river and riverine zone of the reservoir. It should also be noted that while cyanobacteria (blue-green algae) may be more likely to occur in Brownlee Reservoir and the immediate upstream waters, IDEQ (1993a) also observed cyanobacteria (blue-green algae) in the Snake River, and in 1999 and 2000, several canine deaths were ruled to be caused by ingestion of water containing high concentrations of cyanobacteria (blue-green algae) and associated toxins from the Snake River near Burley, Idaho.

When algae in the riverine and transition zones of Brownlee Reservoir die, they are carried further into the reservoir. Their decomposition leads not only to the reduction of oxygen in the water column but also the conversion of particulate organic phosphorus to highly available, highly mobile, dissolved ortho-phosphate. Data collected from the outflow of the reservoir indicates that 50 to 80 percent of the total phosphorus is exported (20 to 50% is being retained). However, the percentage of ortho-phosphate is higher in the outflow than in the inflow to Brownlee Reservoir. This could be due to a number of factors including the hypothesis that ortho-phosphate is low relative to total phosphorus coming into Brownlee because most of the total phosphorus is bound in algal cells rather than in solution as ortho-phosphate (IPCo, 1999d).

Available data and information show impairment of aesthetic and recreational uses due to excessive algal growth and slime production in the upstream sections of the reservoir.

Available data and information indicate that the cold water aquatic life and salmonid rearing designated beneficial uses are often impaired during the summer months in Brownlee Reservoir due to low dissolved oxygen concentrations. Concerns related to increased mercury methylation due to anoxia and presence of excessive organic matter are also present, especially in the upstream segment of the reservoir.

pH.

The Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach is listed for pH. Additional, more detailed information on pH is included in Section 3.4.

General Concerns. See Section 2.2.4.4.

Water Quality Targets. See Section 2.2.4.4 and Table 2.2.2.

Common Sources. See Section 2.2.4.4.

Historical Data. Data collected from 1968 to 1974 by the US EPA in the Brownlee Reservoir segment (near Brownlee Dam) show pH values that average 8.0. No depth information is available with these data so location and water column variations are not known. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974a and 1975).

Current Data. As outlined in Table 2.3.19, pH levels have been monitored over a long period of time in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Currently available inflow pH data for the SR-HC TMDL reach includes the inflowing tributaries and the mainstem Snake River. These data show the lowest pH observed in the Brownlee Reservoir to be 7.4. The highest pH observed was 9.6. Less than 5 percent of the data were outside of the pH target established for this TMDL process (n = 529, 25 data points showed exceedences, 4.7%).

Table 2.3.19 pH monitoring for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	pH Monitoring Dates	Source
Brownlee Reservoir (RM 335 to 285)	1990 to Present 1959 to 1996	IPCo, 1999d, 2000c US EPA STORET data, 1998a

Segment Status. An evaluation of all inflowing and mainstem pH data showed that less than 5 percent of the data exceed water quality targets. The lowest pH observed in the Brownlee Reservoir was 7.4. The highest average pH observed was 9.6. Of 529 data points, 25 showed extremes outside of the pH target established for this TMDL process. Figure 2.3.21 shows a summary of pH data for 1992, 1995, and 1997.

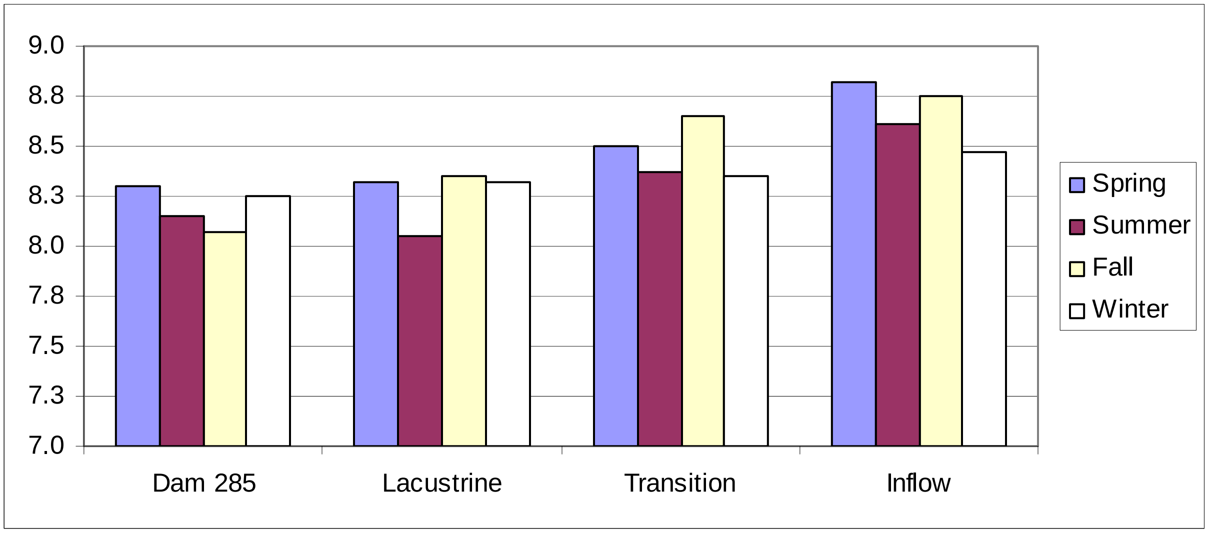


Figure 2.3.21 Mean pH values for the Brownlee Reservoir segment of the Snake River - Hells Canyon TMDL reach (RM 335 to 285).

Based on all the data, a recommendation has been made to delist the mainstem Snake River (RM 335 to RM 285, Brownlee Reservoir) for pH on the State of Idaho, 303(d) list. This proposed delisting will be included as part of the first 303(d) list submitted by the State of Idaho subsequent to the approval of the SR-HC TMDL. However, monitoring of pH levels will continue to be an integral part of the water quality monitoring of the Brownlee Reservoir segment (RM 335 to RM 285).

Sediment.

The Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach is listed for sediment. Additional, more detailed information on sediment is included in Section 3.5.

General Concerns. See Section 2.2.4.5. Additional concerns are associated with sediment-bound mercury, pesticides and nutrients.

Water Quality Targets. See Section 2.2.4.5 and Table 2.2.2.

Common Sources. See Section 2.2.4.5

Sediment transport, and the transport and delivery of sediment-bound pollutants are directly associated with increased flow volumes and high velocities. The change in velocity within Brownlee Reservoir acts to deposit sediments within the reservoir and alters the more random distribution of sediment and sediment-bound pollutants that would be expected in a free-flowing system. Larger size sediment particles (sands and gravels) and the associated sediment-bound pollutants tend to accumulate in the upper portion of Brownlee Reservoir near the transition zone. Smaller particles are carried further downstream in the reservoir. Silt and clay particles tend to drop out closer to the dam site, while even smaller particles and the colloidal matter are often carried through the dam and further downstream. While this deposition acts to reduce the overall concentration of such sediment and sediment-bound pollutants downstream, it localizes the sediment and pollutant mass which can lead to substantial effects on water quality if the reservoir experiences low dissolved oxygen levels at the sediment/water interface. Both sediment-bound mercury and adsorbed nutrients can be released under anoxic conditions and become highly mobile through methylation or dissolution processes. Sediment can also be re-entrained in the water column if management practices result in substantial drawdowns (as in high-water years where Brownlee Reservoir is drawn down for flood control under the direction of the US Army Corps of Engineers).

Deposition in Brownlee Reservoir can also lead to conditions where designated beneficial uses are negatively impacted by a decrease in naturally occurring sediment in the downstream segments. For example, reduced availability of gravel-sized particulate downstream may reduce available spawning habitat for bed spawning fish species.

Historical Data. Anecdotal information available indicates that this segment of the SR-HC TMDL reach has historically carried a substantial sediment load particularly during spring runoff. However there is little quantitative data from earlier periods (particularly prior to the construction of the Hells Canyon Complex).

Current Data. Total suspended sediment data have been collected for the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach as shown in Table 2.3.20. Currently available inflow and in-reservoir data for Brownlee Reservoir include aqueous samples from within the reservoir and major tributaries discharging into the Brownlee Reservoir segment of the SR-HC TMDL reach. The data represent both grab samples and depth-integrated information. While some total suspended sediment data are available from US EPA (US EPA, 1998a), the majority of in-reservoir data has been collected by IPCo.

Table 2.3.20 Total suspended solids (TSS) monitoring for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	Sediment Monitoring Dates	Source
Brownlee Reservoir (RM 335 to 285)	1992, 1995, 1997 1967 to 1996	IPCo, 1999d, 2000c US EPA STORET data, 1998a

At and below the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data collected during the late summer months show the levels of total suspended sediment to range between 2 mg/L and 20 mg/L. While these data do not show instantaneous values that are in excess of those identified as sediment targets for the SR-HC TMDL, they were not collected in a fashion that would allow determination of duration. However, the maximum concentrations observed are well below the 50 mg/L monthly average sediment target established by the SR-HC TMDL.

Above the thermocline, near the dam and in the lacustrine portion of the reservoir, combined data collected show the levels of total suspended sediment to range between a low of 2 mg/L to 20 mg/L, and a high of 25 mg/L to 32 mg/L. While these data do not show instantaneous values that are in excess of those identified as sediment targets for the SR-HC TMDL, they were not collected in a fashion that would allow determination of duration. However, the maximum concentrations observed are well below the 50 mg/L monthly average sediment target established by the SR-HC TMDL.

In the transition and inflow portions of the reservoir, combined data collected during the mid-summer and winter months show the levels of total suspended solids to range between a low of 2 mg/L to 12 mg/L, and a high of 71 mg/L to 196 mg/L. The highest total suspended solids values were observed in March, April and May. While these data show instantaneous values that are in excess of those identified as sediment targets for the SR-HC TMDL, they were not collected in a fashion that would allow determination of duration. However, the maximum concentrations observed are well above the 50 mg/L monthly average sediment target established by the SR-HC TMDL.

Segment Status. Figure 2.3.22 displays the mean total suspended solids concentrations for four representative sections of Brownlee Reservoir as observed from data collected between 1970 and 1999. Total suspended solids data from RM 284 to RM 290 were averaged to show levels for the reservoir near the Brownlee Dam (5.4 mg/L). Total suspended solids data from RM 305 to RM 317.5 were averaged to show levels for the downstream, lacustrine section of the reservoir (9.4 mg/L). Total suspended solids data from RM 320 to RM 330 were averaged to show levels for the transition zone of the reservoir (30.8 mg/L). Total suspended solids data from RM 333 to RM 340 were averaged to show levels for the inflowing river system (56.5 mg/L).

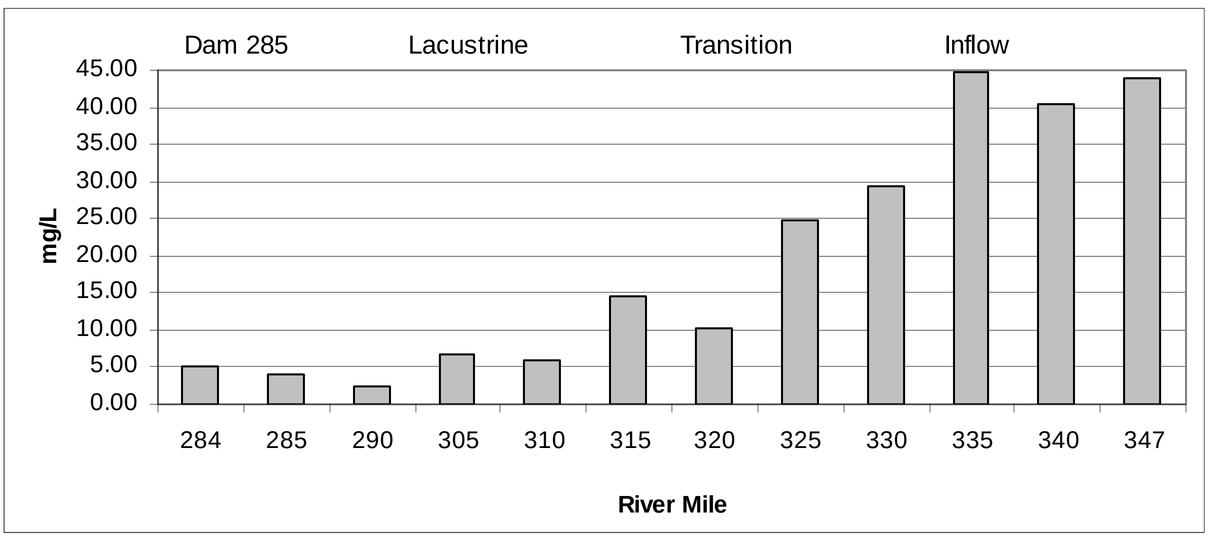


Figure 2.3.22 Mean total suspended solids (TSS) concentrations for the Brownlee Reservoir segment of the Snake River - Hells Canyon TMDL reach (RM 335 to 285).

Total suspended solids concentrations decrease substantially with increasing distance downstream from the reservoir inflow. Depositional and bathymetric assessments of Brownlee Reservoir have shown that the majority of sediment deposition occurs upstream of RM 310 (IPCo, 1999d). An examination of the reservoir at low pool shows that coarse sediment particles drop out in the upstream section of the reservoir near the transition zone while finer silt and clay are carried further downstream. Given the information shown in Figure 2.3.22, events that produce sediment concentrations that exceed the sediment target for the SR-HC TMDL reach would more probably occur in the upstream, riverine and transition zone sections of the reservoir near the inflow of the mainstem Snake River, than in the lacustrine sections of the reservoir closer to the dam.

Available data do not contain duration information and therefore are not sufficient to determine if cold water aquatic life, salmonid rearing, or residential fish and aquatic life designated beneficial uses are impaired due to direct sediment effects. Therefore, sediment targets are set to be protective of these uses. Additionally, due to the fact that sediment acts as a primary transport mechanism for adsorbed pollutants, sediment targets and monitored trends will function as an indicator of changes in transport and delivery for these attached pollutants.

Temperature.

The Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach is listed for temperature due to violations of the Oregon and Idaho water quality standards, including numeric and narrative criteria for salmonid rearing/cold water aquatic life, resident fish and aquatic life. Additional, more detailed information on temperature is included in Section 3.6.

General Concerns. See Section 2.2.4.6.

Water Quality Targets. See Section 2.2.4.6 and Table 2.2.2.

Common Sources. See Section 2.2.4.6.

Historical Data. Available historical temperature data from 1957 collected at the Brownlee Reservoir Dam site (USFWS, 1958) show daily maximum and average temperature measurements that exceed the temperature targets for salmonid rearing/cold water aquatic life identified in the SR-HC TMDL (see Table 2.3.21 and Figure 2.3.23).

Table 2.3.21 Water temperature data for 1957 for the Brownlee Dam site. RM 285 (USFWS, 1958).

	Temperature (°C)	
Month	**Mean Daily Average**	**Mean Daily Maximum**
January	1.6	1.8
February	2.5	2.7
March	6.8	7.1
April	10.0	10.3
May	13.7	14.1
June	18.0	18.6
July	21.6	22.1
August	20.8	21.2
September	17.9	18.3
October	12.3	12.7
November	6.3	6.6
December	3.9	4.1

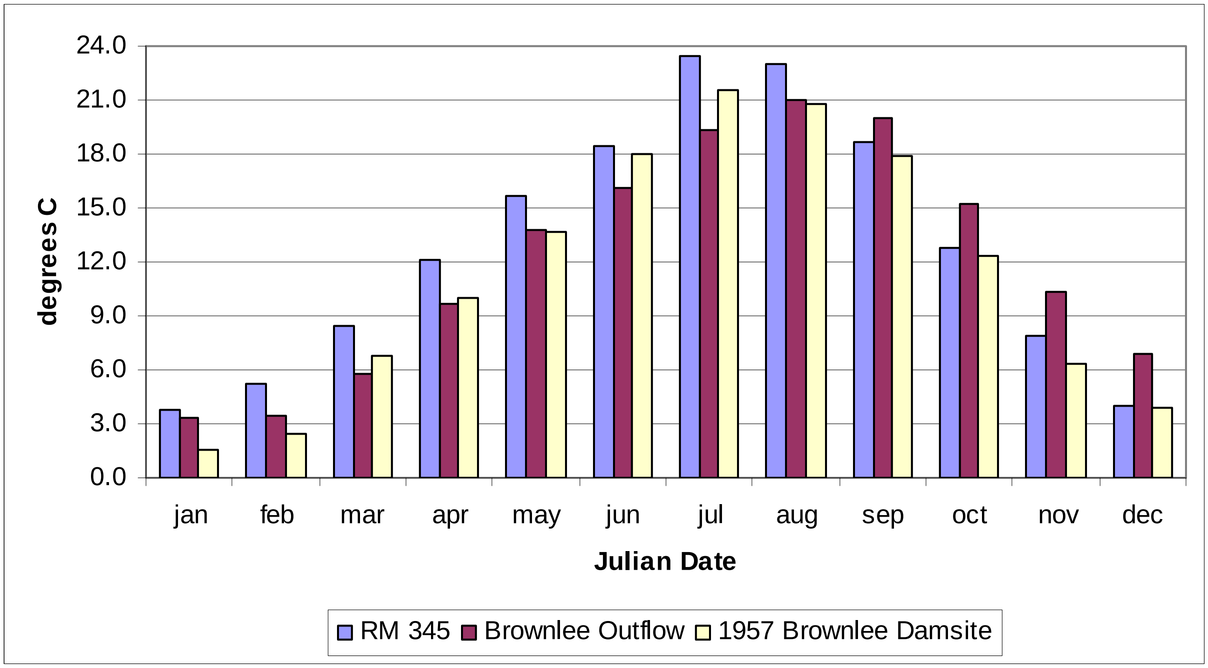


Figure 2.3.23 Current (1990s) vs. historic (1957) mean monthly water temperatures for the Brownlee Reservoir segment of the Snake River - Hells Canyon TMDL reach (RM 335 to 285). (RM 345 is plotted to show the temperature of water inflowing to Brownlee Reservoir.)

Photo 2.3.3. The mainstem Snake River upstream of the Brownlee Dam site (RM 285), circa 1939 to 1940, relatively low water years. Photo from the collection of Dr. Lyle M. Stanford.

These data, when combined with information on historical water management occurring upstream of RM 285 and available air temperature data, indicate that waters in this segment probably experienced warming due to both anthropogenic and non-anthropogenic sources prior to dam construction. Data collected from 1968 to 1974 by the US EPA in the Brownlee Reservoir segment (near Brownlee Dam) show temperature values that average 14.5^{o} C. No depth information is available with these data so location and water column variations are not known. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974a and 1975).

Current Data. Current temperature data available for the Brownlee Reservoir segment (RM 335 to 285) include monitoring of both tributary and mainstem values (Table 2.3.22). Extensive water temperature data was collected for Brownlee Reservoir from 1990 to present. Water temperature data have been collected for many areas of the Brownlee Reservoir segment and a variety of depths. Collection frequency and data type (daily max, daily average, instantaneous measurements, etc.) vary widely. Concurrent air temperature data for some areas extends back to the 1950's and represents a range of seasonal and annual climate variations. Daily maximum, mean and minimum air temperatures are recorded for the last 10 years for the Brownlee Reservoir station (SNOTEL, 2000).

Table 2.3.22 Temperature monitoring information for the Brownlee Reservoir segment (RM 335 to 285) of the Snake River - Hells Canyon TMDL reach.

Segment	Temperature Monitoring Dates	Source
Brownlee Reservoir (RM 335 to 285)	1993 1957 1992, 1995, 1997 1960, 1967 to 1996	IDEQ, 1993a USFWS, 1958 IPCo, 1999d US EPA STORET data, 1998a

Segment Status. A plot of 1957 (pre-dam completion) vs. current temperature in the Brownlee Reservoir Segment (RM 335 to 285) is shown in Figure 2.3.23. A single year of data is available for pre-impoundment conditions so comparisons can be made to this year only and may not be indicative of overall trends. The location of the 1957 data is referenced only as the Brownlee Dam site (USFWS, 1958) so it is assumed that the location is that of the present-day dam site, RM 285. The current data shown are average surface-water temperatures from 1991 through 2001 from RM 285 (the dam site) and RM 345 (the inflow to the reservoir). The plotted data show that the magnitude of surface water temperatures at RM 285 pre- and post-impoundment are relatively similar, with the post-impoundment temperature maxima being approximately 1 ^{o}C cooler than the pre-impoundment maxima observed in 1957. The timing of temperature maxima has shifted slightly later in the year in the post-impoundment data set from RM 285, with the temperature maxima occurring approximately one month (30 days) later in the 1990s than in 1957. Data sets from both pre- and post-impoundment at RM 285 show substantially cooler summer maximum temperatures (approximately 4 ^{o}C) than those currently observed at the inflow to Brownlee Reservoir (RM 345).

Brownlee Reservoir undergoes strong thermal stratification during summer months (stratification usually occurs from March through November, but is strongest in July and August, exhibiting a ~ 10 ^{o}C change within 60 vertical feet (IPCo, 1999d)). The position of the thermocline is well correlated with the level of the powerhouse penstocks, and extends approximately 25 miles upstream of the dam (IPCo, 1999d).

Temperatures that exceed the SR-HC TMDL targets for salmonid rearing/cold water aquatic life have been observed routinely at the inflow of Brownlee Reservoir and throughout the length of the reservoir in the surface waters. Most of these exceedences occur during the months of July and August, with surface temperature readings of 22 to 24 ^{o}C (72 to 75 ^{o}F) not uncommon.

Unlike Oxbow and Hells Canyon reservoirs, which receive cooled inflows from Brownlee Reservoir, the major source of inflowing water to Brownlee Reservoir is the Snake River. As discussed above, as the water in the mainstem Snake River moves downstream between RM 409 and 335, it maintains a relatively wide, shallow profile in a predominately dry and sparsely forested climate region. As this incoming water passes through Farewell Bend and into the transition zone of the reservoir, there is little opportunity for shading. During summer months, the daily average air temperatures at Brownlee Reservoir routinely reach 29 ^{o}C (84 ^{o}F) with 32 to 35 ^{o}C (90 to 95 ^{o}F) common as a daily maximum average in July and August. Inflowing water temperatures for these months reflect these elevated air temperatures with averages of 22 to 24 ^{o}C (72 to 75 ^{o}F) (IPCo, 1999d; IDEQ, 1993a).

Within the reservoir, deep water (below the thermocline) maintains a fairly stable summer temperature of 10 ^{o}C (50 ^{o}F) or less at the dam (Ebel and Koski 1968; IPCo, 1999c), while surface waters in the same area vary from 20 to 28 ^{o}C (68 to 82 ^{o}F). During the winter season, the reservoir is not strongly stratified and the difference between deep water temperature averages (4 ^{o}C (39 ^{o}F)) and surface water temperature averages (4 to 6 ^{o}C (39 to 43 ^{o}F)) is less. Due to the short residence time, the temperature of the surface water moving downstream through Brownlee reservoir in the summer changes by about 2 to 4 ^{o}C (4 to 6 ^{o}F) from Farewell Bend to Brownlee Dam. There are relatively few watershed-based anthropogenic temperature sources within the Brownlee Reservoir area. Both the Powder and the Burnt Rivers flow into Brownlee Reservoir, contributing 2.9 percent and 0.7 percent of the total flow respectively. Both river systems pass through relatively hot, dry, sparsely vegetated drainages before inflowing to the reservoir.

Temperatures that exceed the SR-HC TMDL salmonid rearing/cold water aquatic life at the inflow of the Powder River have been observed to occur from July through September. A temperature TMDL is scheduled to be written by the State of Oregon in 2006 for the Powder River system. Seasonal temperature increases within the Powder River are most likely influenced to some extent by natural heat exchange through high air temperatures and solar radiation, i.e. lack of shade.

Temperatures that exceed the SR-HC TMDL targets for rearing/cold water aquatic life have also been observed at the mouth of the Burnt River. Most of these events occurred during the months of July and August. A temperature TMDL is scheduled to be written by the State of Oregon in 2006 for the Burnt River system. As noted for the Powder River system above, seasonal temperature increases within the Burnt River are most likely influenced to some extent by natural heat exchange through high air temperatures and solar radiation.

The flow contribution of both the Powder and the Burnt Rivers is relatively small (less than 4%) when compared to the total flow within Brownlee Reservoir. Changes in temperature within Brownlee Reservoir due to the Powder and Burnt River inflows are therefore assumed to be minimal.

Please note: Assessments of water quality data in reference to the SR-HC TMDL targets for the tributary inflows to the Brownlee Reservoir segment (RM 335 to 285) are based on the operating assumption that salmonids and other cold water aquatic life within the reservoir have the potential to use the mouths of the inflowing tributaries for cold water refugia during summer months. These assessments are not intended to imply that salmonid rearing and cold water aquatic life (if not currently designated beneficial uses) are or should be designated beneficial uses of the tributaries, or that standards violations are occurring upstream within the tributary drainages.

Available data show exceedences of temperature criteria throughout the surface waters of the SR-HC TMDL reach during the months of June, July, August and September. Cold water aquatic life and salmonid rearing designated uses are supported in the Brownlee Reservoir segment (RM 335 to 285) due to the presence of cold water refugia.

2.3.2.3 DATA GAPS

See Section 2.4

2.3.2.4 POLLUTANT SOURCES

See Section 2.5

Point Sources

There are no known permitted point sources that discharge directly to Brownlee Reservoir, however, permitted discharges to the inflowing Burnt River and Powder River systems do occur. These include treated municipal sewerage discharges, municipal stormwater discharges and industrial discharges.

Point sources discharging to tributaries will not receive a separate waste load allocation. A "bulk" load allocation has been identified for the mouths of the tributaries. The identification of load and waste load allocations specific to the tributary loading will be accomplished through the tributary TMDL process in the case of those tributaries that do not yet have a TMDL in place and as part of the TMDL implementation plan process in the case of tributaries where a TMDL is already in place.

Nonpoint Sources

Nonpoint sources discharging to the mainstem Snake River in the SR-HC TMDL reach include agricultural, recreational, urban/suburban, and forestry land use, as well as ground water and natural and background loading.

Agricultural.
A minor amount of the agricultural land (3.0 %) within the SR-HC TMDL reach is located in the drainage areas of the Burnt and Powder river systems that drain into the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Predominant agricultural practices within these drainages include irrigated and dryland pasture (grazing). A limited amount of cropping occurs within the Brownlee Reservoir drainage. Only very minimal agricultural return flows have been identified within the Brownlee Reservoir segment of the SR-HC TMDL reach. Grazing occurs throughout this segment but animal densities are minimal.

Recreational.
Due to its proximity to populated urban areas and the excellent recreational opportunities available, Brownlee Reservoir is a major destination site year-round. Water-based recreational activities peak in the summer season with heavy use observed between Memorial Day weekend and Labor Day weekend, when the reservoir is used by many boaters, swimmers, campers and anglers. The average use of the reservoir (May 1997 through October 1998) is estimated at 591,887 visitor hours annually. Peak use during a week has been estimated at 45,959 visitor hours (July 4th), and monthly peak use levels estimated at 13,878 visitor hours (June). Camping and bank-fishing use is also substantial (IPCo, 2000b; HCNRA, 1998a and 1998b, 1999a and 1999b).

Urban/Suburban.
A minimal amount of the urban/suburban land within the SR-HC TMDL reach is located in the drainage areas of the Burnt and Powder River systems that drain into the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Rural residential housing supported by septic systems is present within this segment but densities are minimal.

Ground Water.
Many natural springs and ground-water inflows have been observed in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. These inflows occur in the tributary drainages and the reservoir system, entering both above and below the water level in many locations. Subsurface recharge from irrigation water use is estimated to be minimal in the Brownlee Reservoir segment due to low irrigation water usage in this area. Natural ground-water inputs are estimated to dominate over subsurface recharge in most areas of this segment.

Background and Natural Contributions.
The natural sources discussed in Section 2.5 are known to be present to some degree in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. The occurrence of natural sources of mercury is more prevalent in tributaries to the Upstream Snake River and Brownlee Reservoir segments than in the segments located downstream.

Internal Recycling and Reservoir Water Levels.
As discussed previously, the placement and operation of hydroelectric impoundments within the SR-HC TMDL reach, in combination with poor inflow water quality have the potential to exacerbate declining water quality conditions. The Hells Canyon Complex impoundments alter the physical characteristics of the mainstem Snake River and contribute to changes in water quality, aquatic habitat, and designated beneficial use support. Riverine characteristics affected by the hydroelectric impoundments include water velocity, discharge, water depth, and water retention times. Water quality parameters potentially affected by the operation of the Hells

Canyon Complex hydropower projects include dissolved oxygen, water temperature, gas supersaturation, sedimentation, and instream processing of nutrients and organic matter. While the hydropower plants do not add nutrients or organic matter to the river, processing is altered and flushing of pollutants downstream is reduced. The impoundments behind the dams have an effect on the ability of the river to process sediment and nutrients (USDA-USFS, 1997), and organic matter.

Water quality in the SR-HC TMDL reach is degraded due to point and nonpoint source pollutant loads, compounded by managed, altered, or reduced flows and velocities due to storage and diversion throughout the watershed. These factors, in combination with natural climatic and pollutant sources, have resulted in the increased growth of nuisance aquatic vegetation and decreased dissolved oxygen levels. High productivity in the upstream Snake River and the transition and riverine zones of the reservoir, and decomposition of aquatic vegetation in both the river and reservoir causes low dissolved oxygen levels in the water column and result in non-support of designated beneficial uses. Oxygen deficits observed throughout the water column in Brownlee Reservoir commonly occur during the summer months (low dissolved oxygen occurs in both stratified and non-stratified areas) and become increasingly oxygen poor as the summer stratification strengthens (IPCo, 1999d).

As previously stated, hydroelectric projects do not add nutrients to the river, instead nutrient processing is intensified and flushing of pollutants downstream is reduced. The impoundments behind the dams may affect the ability of the river to process sediment and nutrients. Thus, the dams in the SR-HC TMDL reach have modified water quality conditions in two ways: (1) altering the processing (including sedimentation) of nutrients and organic matter within Brownlee Reservoir and (2) reduced nutrient and sediment loading to Oxbow and Hells Canyon reservoirs, and the river downstream of Hells Canyon Dam. The general result is increased sediment deposition within the reservoir and decreased movement of sediment and, to some extent, associated pollutant loads downstream.

In addition to the physical and flow changes discussed above, phosphorus contained in river and reservoir bed sediments represents a potential loading source to the water column. While the reservoir acts as a nutrient sink under most conditions, some nutrients are released from the sediments. Most nutrient release occurs during periods of anoxia (Figure 2.3.15, 2.3.17, and 2.3.18), when stratification acts to inhibit transport of higher nutrient concentrations to the surface waters. Due to this fact, most of the recycled nutrients within the reservoir are not directly available to algal growth in Brownlee, but are discharged through the dam into the downstream reservoirs of Oxbow and Hells Canyon. The deposition, release and dissolution of this phosphorus is dependent on both physical and chemical processes within the watershed, river and reservoir. Physical processes dominate in the transport of phosphorus contained within or adsorbed to sediment and particulate matter. Chemical processes dominate in the transport of dissolved phosphorus and in the transformation of phosphorus from one form or state (i.e. free or adsorbed) to another, within both the transport pathway through the reservoir and the water column.

Phosphorus within the water column can be divided into two major sources: suspended, particulate-bound or sorbed phosphorus (both organic and inorganic), and dissolved phosphorus.

Suspended matter can be colloidal in nature (under 0.45 µm in diameter) and resist settling forces because the surface area to mass ratio is high enough that internal buoyancy counteracts gravitational forces. Sediment and organic matter that has settled to the river and reservoir bed may also become re-suspended and act as a source of dissolved phosphorus as the chemical environment within the water column or channel substrate changes. (Note: This is also true in the Snake River upstream, where sediment bound phosphorus is continually recycled into the water column and constant interchange occurs between the water column and sediments). Dissolved phosphorus may be present in the mainstem and tributary inflows, or as phosphorus released from bed-sediments.

Phosphorus release from bed sediments has been observed under anaerobic conditions (IPCo, 1999d). This release, along with phosphorus release from deposition/decomposition processes can be observed in the data plotted in Figures 2.3.17 and 2.3.18. An increase in both total and dissolved reactive phosphorus is observed to occur at approximately RM 310 in Brownlee Reservoir. This location corresponds well with known depositional processes within the reservoir, and can be correlated with finer, suspended sediment and algae that would potentially be transported slightly farther than the coarse material that deposits near RM 325. The increase in concentration observed is most likely a combination of both benthic release and decomposition/dissolution processes occurring at the sediment/water interface.

Low dissolved oxygen is a primary mechanism in the benthic release of adsorbed constituents. Phosphorus sorption sites are related to the charge state and concentration of iron and aluminum within sediment particles. Under anaerobic conditions, the charge state of iron is changed, resulting in the release of bound phosphorus to the overlying water column as sorption potential is decreased (Sharpley *et al.*, 1995). Low dissolved oxygen concentrations lead to increased sediment release of bound phosphorus in this manner. In comparing Figures 2.3.15, 2.3.17 and 2.3.18, areas of low dissolved oxygen are well correlated with areas of increased phosphorus concentration at the sediment/water interface. Similar processes can occur in a riverine environment where intergravel anoxia occurs. Again, because the upper boundary of the hypolimnion is generally located at a depth of approximately 45 meters in Brownlee Reservoir, most of this recycled phosphorus is retained in the hypolimnion and is generally not available for primary productivity.

Similar to benthic release of nutrients, anoxic conditions can act to increase the conversion of elemental and inorganic mercury to methylmercury as mentioned previously. This process, and the associated aquatic life, wildlife, and human consumption concerns are discussed in greater detail in Section 3.1.

Strong thermal stratification within Brownlee Reservoir during the summer months acts to reduce the transport of dissolved and desorbed phosphorus, and methylmercury to the surface waters. During stratification, cooler, denser water layers tend to remain relatively stationary within the lower levels of the reservoir. Increased phosphorus and/or methylmercury concentrations occurring within these waters are not immediately equilibrated with surface waters due to a lack of circulation within the stratified reservoir system. Equilibration occurs with winter turnover or mixing of the reservoir, commonly later in the year when surface water temperatures are no longer ideal for algal growth.

Availability of sediment-bound phosphorus and potential leaching into surface water can also be affected by operational conditions controlling the water depth over the reservoir sediments and by thermal stratification within the reservoir. Fluctuating water levels that periodically expose sediments or alter the aerobic/anaerobic conditions at the sediment/water interface affect the sink/source characteristics of these sediments. Under extreme drawdown conditions, sediment phosphorus availability may be increased, further contributing to the enrichment of the water column and increased algal productivity. This is not thought to represent as important a process as the nutrient cycling described previously however.

Note: The organic matter processing in Brownlee Reservoir reduces organic matter loads to downstream reservoirs and river reaches. While this leads to dissolved oxygen problems in Brownlee Reservoir and downstream, it limits organic matter deposition and related low dissolved oxygen levels in the salmon spawning gravels below the reservoirs. However, it is better for water quality within the system as a whole to limit the initial organic matter loading rather than to rely on instream processing (ODEQ, 1999)

2.3.2.5 Pollution Control Efforts

See Section 2.6

Other TMDL Efforts
In addition to this SR-HC TMDL effort, sediment TMDLs are scheduled for the Burnt and Powder rivers and many of the smaller tributaries to the SR-HC system. It is expected that, if successfully implemented, these TMDL efforts will result in improvement of sediment concentrations within these segments.

No other TMDLs or watershed management plans are currently in place in the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach.